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Drainage and impregnation capillary pressure curves calculated by the X-ray CT model of Berea sandstone using Lattice Boltzmann's method

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Abstract

 The study deals with the features of the technique for simulating the capillary pressure curves of porous media on their X-ray microtomographic images. The results of a computational experiment on the immiscible displacement of an incompressible fluid by another in the pore space represented by a digital image of the Berea sandstone are presented. For the mathematical description of two-phase fluid flow we use Lattice Boltzmann Equation (LBM), and phenomena at the fluids interface are described by the color-gradient model. Compared with laboratory studies, the evaluation of capillary pressure based on the results of a computational filtration experiment is a non-destructive method and has a number of advantages: the absence of labor for preparation of fluids and core; the possibility of modeling on the scale of very small core fragments (several mm), which is difficult to realize under experimental conditions; three-dimensional visualization of the dynamics of filling the pore space with a displacing fluid during drainage and impregnation; the possibility of carrying out multivariate calculations for specified parameters of multiphase flow (density and viscosity of fluids, surface tension, wetting contact angle). A satisfactory agreement of the capillary pressure curves during drainage with experimental results was obtained. It is revealed that with the increase in the volume of the digital image, the relative deviation of the calculated and laboratory data decreases and for cubic digital cores larger than 1 mm it does not exceed 5%. The behavior of the non-wetting fluid flow during drainage is illustrated. It is shown that flow regimes under which computational and laboratory experiments are performed the distribution of the injected phase in directions different from the gradient of the hydrodynamic drop, including the opposite ones, is characteristic. Experimentally confirmed regularities are obtained when carrying out calculations for drainage and imbibition at different values of interfacial tension. There is a close coincidence in the average diameters of permeable channels, estimated by capillary curves for different interfacial tension and pore network model. The differences do not exceed 15%.

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